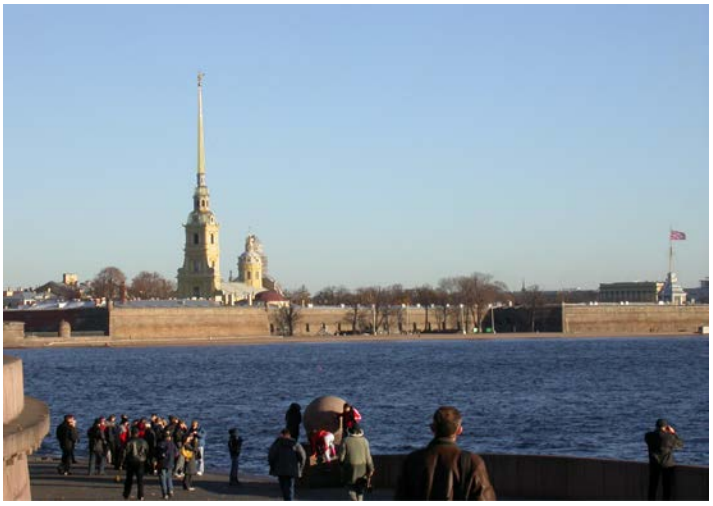

Absolute Gravity Measurements in Lomonosov, Saint-Petersburg, Russia

Final Report

November 2004

Prof. Dr. Olivier Francis
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Foreword

The D.I. Mendeleyev All-Russian Institute for Metrology (VNIIM) is the successor of the Depot of Standard Measures and Weights, the first Russian metrological establishment and one of the oldest in the world. It was formed in Saint-Petersburg in 1842 and later on transformed, at first into the Main Chamber of Measures and Weights, then into the All-Union Research Institute for Metrology. In 1945, the Institute was named after the great Russian scientist, the founder of scientific metrology, D.I. Mendeleyev. Today, VNIIM is one of the largest world centers for research and practical metrology. Metrology is the science dealing with precise measurements and methods for assuring their traceability to measurement standards.

For the need of the scientists at the VNIIM, absolute gravity measurements with a state-of-the art absolute gravimeter (Figure 1) were carried out in November 2004 in their Institute. The absolute gravimeter, from the European Center for Geodynamics and Seismology (ECGS, Luxembourg), was operated by Prof. Olivier Francis.

Figure 1. The absolute gravimeter FG5#216 from the ECGS at the Lomonosov gravimetric site.

The Absolute gravimeter

The most accurate, and in fact the only commercially available absolute gravimeter, is the FG5 from Micro-g Solutions Inc. (Niebauer et al., 1995). With this instrument, the gravitational acceleration is observed directly. A test mass is repeatedly dropped and its position is measured as a function of time. The position and time measurements are directly linked to fundamental standards of length and time using lasers and atomic clocks. The FG5 is portable and has been used to measure absolute gravity all over the world. On the other hand, the instrument is not well suited for continuous measurements lasting longer than a few days. The noise of a FG5 at a quiet site is around 22 μGal/$\sqrt{Hz}$, however, noise levels as low as 5 μGal/$\sqrt{Hz}$ have been observed (Francis et al., 1998). The instrumental accuracy of the FG5 is about 1-2 microgal as reported by the manufacturer (Niebauer et al., 1995). However, because we cannot model the environmental effects perfectly, the precision in practice is on the order of a few microgal.

Location

The VNIIM is located close to the small town of Lomonosov on the Southern coast of the Gulf of Finland at 40 km from St-Petersburg (Figure 2).

Figure 2. Map around Saint-Petersburg, Lomonosov is highlighted in the red rectangle

The gravity site is located in the building of the Department of Low-Frequency Mechanical Motion Quantities, Gravimetry and Angle Metrology (Figure 3).

Figure 3.

Inside the building (Figure 4), there is a monolithic concrete basement isolated from the main Building. Its mass is about 4,000 tons. One of the nine boxes hosts the absolute gravimetric site, which is one of the nodes of the Russian gravimetric network.

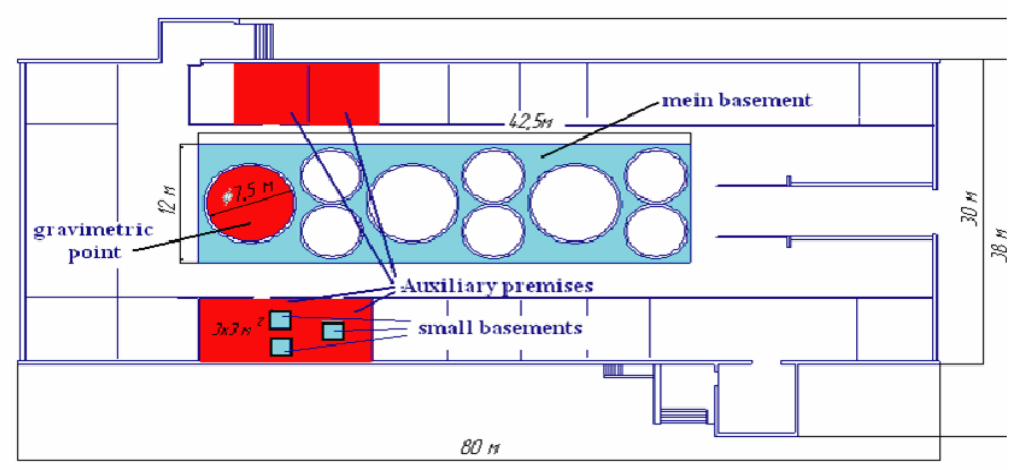


Figure 4. Layout of the building of the Department of Low-Frequency Mechanical Motion Quantities, Gravimetry and Angle Metrology in Lomonosov.

Data processing

Raw data from the absolute gravimeters consist of vectors of time and position of the falling object during the drops. To obtain the gravity value, a linear equation representing the equation of motion is fit to the raw data including the gravity gradient which still need to be measured with a relative meter (for now, a theoretical value of –3 microgal/cm has been used).

The data processing follows the protocol adopted during absolute gravimeters comparisons at the BIPM in Sèvres (Francis and van Dam, 2003). Geophysical corrections are applied to the raw gravity data: earth tides (from state-of-the art model), atmospheric pressure effect using a constant admittance, and the polar motion effect using pole positions from IERS.

The g-soft version 4.0 software from Micro-g Solutions Inc. was used for the processing. All the text outputs as well as some figures are compiled in this report for future reference.

Results of the absolute gravity measurements

The table 1 contains the final values of g (gravity acceleration) at the Lomonosov gravimetric point. Two datasets were have been obtained over 3 days. The results for each dataset are presented as well as for the combined data set. A total of 6,700 drops were carried out.

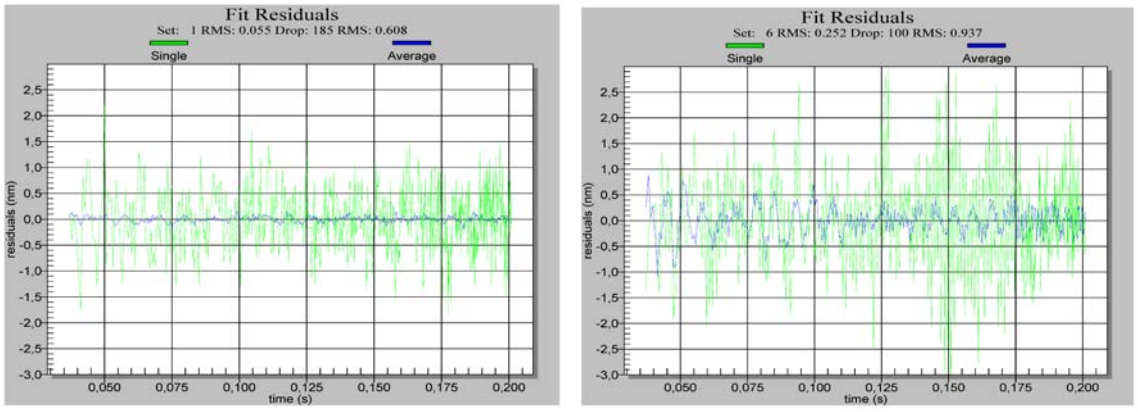
The results of both datasets are very close. The precision of the first dataset is lower that the second one. This could be due to the time required for the instrument (vacuum, mechanical and electronics components) to reach its stable conditions. Another source could be due to the microseismic noise, which can be non-negligible at a coastal station. We decided to change the sampling from 10 seconds to 5 seconds for the second set. This should reduce the aliasing of the microseismic noise into the low frequency band.

Table 1. Summary of the absolute gravity measurements at Lomonosov

Station	Date	Gravity value /microgal	Standard Deviation/microgal	Drop-to-drop Standard Deviation/microgal
Lomonosov	4-5 November 2004	9 81 902 491.36	2.8	21.3
	5-6 November 2004	9 81 902 491.45	0.9	21.6
Lomonosov				
Combined dataset	***4-6 November 2004***	***9 81 902 491.45***	***1.9***	***21.4***

Conclusions

Overall the results are excellent. A precision of about 1 microgal is reached in the second dataset. We should mention that the drop-to-drop standard deviation is quite high around 20 microgal when compared to a quiet station (about 5 microgal). Nonetheless, it did not affect the averaged g-value. The gravimetric point at Lomonosov can be considered as a good gravimetric site. The excellent stability of the basement has been confirmed as shown by the low amplitude and the absence of pattern drop residuals (Figure 5).



A **B**

Figures 5. Comparison between the drop residuals at Lomonosov (A) and at the station (B) with a bad basement where the so-called recoil effect is visible.

We recommend to carry out one absolute gravity measurement per year at least. We also encourage to set-up a relative gravimeter for at least 6 months in order to determine the observed tidal parameters. This should improve the tidal corrections, especially for a coastal station where the oceanic loading and attraction effects are difficult to model. Finally, the vertical gravity gradient should be measured again several times with the highest reachable precision.

Acknowledgments

The author would like to thank D. Khanov (Director of the VNIIM) and V. Alexandrov (Deputy Director of VNIIM) for the invitation. He is very grateful to A. Yankovsky and E. Krvitsov for their kind and efficient assistance and logistic support for the experiment. He also is very indebted to A. Sinelnikov for his warm hospitality.

The mission expenses were mainly taken in charge by the European Center of Geodynamics and Seismology. A financial support was also provided by the Council of Europe in the framework of the Agreement EUR-OPA on Major Risks.

References

Francis, O., T.M. Niebauer, G. Sasagawa, F. Klopping and J. Gschwind, 1998. Calibration of a superconducting gravimeter by comparison with an absolute gravimeter FG5 in Boulder, Geophys. Res. Lett., **25**, No 7, 1075-1078.

Francis O., van Dam T.M., Processing of the Absolute data of the ICAG01, Cahiers du Centre Européen de Géodynamique et de Séismologie, vol.22, 45-48, 2003.

Niebauer, T., G. Sasagawa, G. Faller, R. Hilt and F. Klopping, 1995. A new generation of absolute gravimeters, Metrologia, **32**, 159-180.

4-5 Nov. 2005

STATION: SAINT-PETERSBURG

City:	Lomonosov	Country:	Russia
Location:	VNIIM	Particularity:	
Situation:	Gravity site	Remarks:	
Date:	4/5 November 2004		

Code number:	
Latitude:	59.8908 degrees
Longitude:	29.7862 degrees
Elevation:	29.97 m
Gradient:	-3.000 μgal/cm
Reference height:	11.75 mm
Meter:	FG5
S/N:	216

Ocean loading correction (μgal, -Greenwich degree)

Wave	M_2	S_2	K_1	O_1	N_2	P_1	K_2	Q_1	M_f	M_m	S_{sa}
Ampl.	0.510	0.155	0.041	0.143	0.091	0.010	0.040	0.042	0.0	0.0	0.0
Phase:	16.4	-12.0	-18.2	129.3	36.9	31.0	-30.4	-190.0	0.0	0.0	0.0

Polar motion correction			**Air pressure correction**	
X-coordinate:	0.2078	arc seconds	Nominal air pressure:	109.65 mbar
Y-coordinate:	0.3521	arc seconds	Barometric admittance factor:	0.3 μgal/mbar

Gravity

Set gravity mean:	**9 81 902 491.36**	microgal
Set std. dev.:	2.78	microgal
Mean std. dev.:	21.26	microgal
Number of sets:	19	
Number of drops per set:	100	
Drop interval:	10 seconds	
Set interval:	60 minutes	
Nominal/datum height:	0.0 cm	

Author: O. Francis — European Center for Geodynamics and Seismology

Date: January 9, 2005

Project file

Micro-g Solutions g Processing Report
File Created: 01/03/05, 16:23:04

Project Name: SP20041104
g Acquisition Version: 1.0823
g Processing Version: 4.0405

Company/Institution:
Operator: Olivier

Station Data
Name: Saint-Petersbourg
Site Code: Gravity point VNIIM
Lat: 59.89079 Long: 29.78620 Elev: 29.97 m
Reference Height: 11.75 cm
Datum Height: 0.00 cm
Gradient: -3.000 uGal/cm
Nominal Air Pressure: 1009.65 mBar
Barometric Admittance Factor: 0.30
Polar Motion Coord: 0.2078 " 0.3521 "
Earth Tide (ETGTAB) Selected
Potential Filename: C:\Program Files\Micro-g Solutions Inc\gWavefiles\Etcpot.dat
Delta Factor Filename: F:\absolu\DATA\2004\FG5-216\StPetersbourg\OceanLoad.dff
Delta Factors

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0.002428	0.249951	1.160000	0.0000	Long
0.721500	0.906315	1.154250	0.0000	Q1
0.921941	0.974188	1.154240	0.0000	O1
0.989049	0.998028	1.149150	0.0000	P1
0.999853	1.216397	1.134890	0.0000	K1
1.719381	1.906462	1.161720	0.0000	N2
1.923766	1.976926	1.161720	0.0000	M2
1.991787	2.002885	1.161720	0.0000	S2
2.003032	2.182843	1.161720	0.0000	K2
2.753244	3.081254	1.07338	0.0000	M3
3.791964	3.937897	1.03900	0.0000	M4

Ocean Load ON, Filename: F:\absolu\DATA\2004\FG5-216\StPetersbourg\OceanLoad.olf

Waves:	M2	S2	K1	O1	N2	P1	K2	Q1	Mf	Mm	Ssa
Amplitude (uGal):	0.510	0.155	0.041	0.143	0.091	0.010	0.040	0.042	0.000	0.000	0.000
Phase (deg):	-16.4	12.0	18.2	-129.3	-36.9	-31.0	30.4	190.0	0.0	0.0	0.0

Instrument Data
Meter Type: FG5
Meter S/N: 216
Factory Height: 116.40 cm
Rubidium Frequency: 10000000.01020 Hz
Laser: WEO (187)
ID: 632.99117754 nm (0.41 V)
IE: 632.99119473 nm (-0.05 V)
IF: 632.99121259 nm (-0.43 V)
IG: 632.99123023 nm (-0.80 V)
IH: 632.99136890 nm (-1.60 V)
II: 632.99139822 nm (-1.49 V)

IJ: 632.99142704 nm (-1.40 V)
Modulation Frequency: 8333.420 Hz

Processing Results
Date: 11/04/04
Time: 20:58:15
DOY: 309
Year: 2004
Gravity: 981902491.36 uGal
Set Scatter: 2.78 uGal
Measurement Precision: 0.64 uGal
Total Uncertainty: 0.64 uGal
Number of Sets Collected: 19
Number of Sets Processed: 19
Set #s Processed: 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
Number of Sets NOT Processed: 0
Set #s NOT Processed:
Number of Drops/Set: 100
Total Drops Accepted: 1897
Total Drops Rejected: 3
Total Fringes Acquired: 700
Fringe Start: 20
Processed Fringes: 600
GuideCard Multiplex: 4
GuideCard Scale Factor: 250

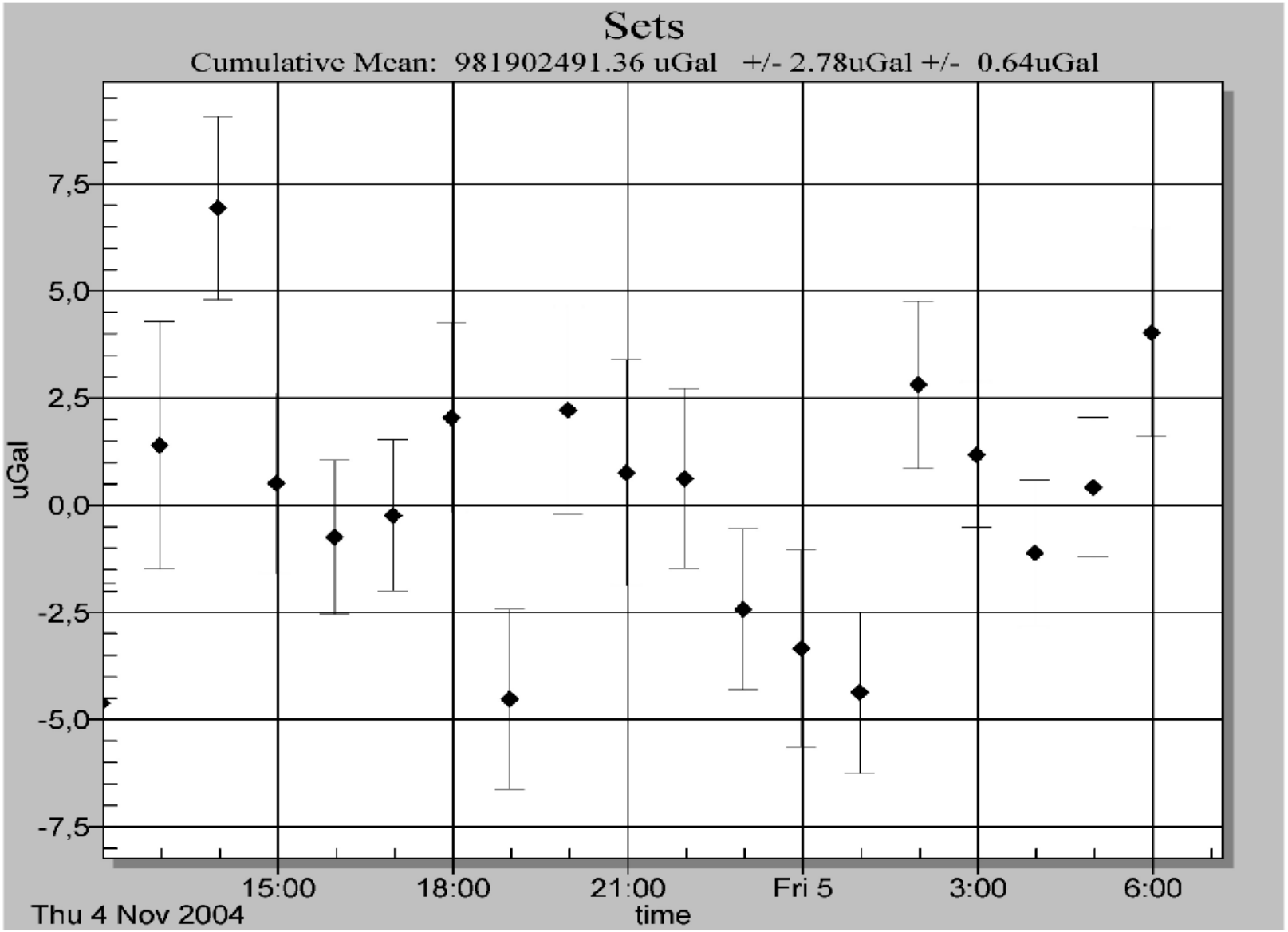
Gravity Corrections
Earth Tide (ETGTAB): -25.81 uGal
Ocean Load: 0.12 uGal
Polar Motion: -0.09 uGal
Barometric Pressure: -0.43 uGal
Datum Height: 384.45 uGal
Reference Xo: 0.00 uGal

Uncertainties
Earth Tide Factor: 0.000
Average Earth Tide Uncertainty: 0.00 uGal
Ocean Load Factor: 0.00
Average Ocean Load Uncertainty: 0.00 uGal
Barometric: 0.00 uGal
Polar Motion: 0.00 uGal
Laser: 0.00 uGal
Clock: 0.00 uGal
System Type: 0.00 uGal
Tidal Swell: 0.00 uGal
Water Table: 0.00 uGal
Unmodeled: 0.00 uGal
System Setup: 0.00 uGal
Gradient: 0.00 uGal (0.00 uGal/cm)

Set File

Source Data Filename: SP20041104
g Acquisition Version: 1.0823
g Processing Version: 4.0405

Set	Time	DOY	Year	Gravity	Sigma	Error	Uncert	Tide	Load	Baro	Polar	Datum	Refxo	Temp	Pres	Accept	Reject	
1	11:58:15	309	2004	981902486.740	28.013	2.801	2.801		-74.922	0.111	0.304	-0.090	384.450	0.003	25.822	1010.668	100	0
2	12:58:15	309	2004	981902492.756	28.842	2.884	2.884		-77.871	0.263	0.042	-0.090	384.450	0.003	25.313	1009.794	100	0
3	13:58:15	309	2004	981902498.294	21.351	2.135	2.135		-77.744	0.336	0.028	-0.090	384.450	0.003	25.221	1009.750	100	0
4	14:58:15	309	2004	981902491.872	21.012	2.112	2.112		-75.068	0.320	0.013	-0.090	384.450	0.003	25.215	1009.699	99	1
5	15:58:15	309	2004	981902490.616	18.033	1.803	1.803		-70.373	0.227	-0.069	-0.090	384.450	0.003	25.233	1009.425	100	0
6	16:58:16	309	2004	981902491.121	17.552	1.764	1.764		-64.095	0.086	-0.162	-0.090	384.450	0.003	25.226	1009.116	99	1
7	17:58:15	309	2004	981902493.406	22.206	2.221	2.221		-56.539	-0.060	-0.235	-0.090	384.450	0.003	25.276	1008.873	100	0
8	18:58:15	309	2004	981902486.834	21.025	2.103	2.103		-47.853	-0.170	-0.314	-0.090	384.450	0.003	25.294	1008.608	100	0
9	19:58:15	309	2004	981902493.577	24.219	2.422	2.422		-38.104	-0.213	-0.369	-0.090	384.450	0.003	25.336	1008.424	100	0
10	20:58:15	309	2004	981902492.118	26.367	2.637	2.637		-27.357	-0.177	-0.402	-0.090	384.450	0.003	25.318	1008.315	100	0
11	21:58:15	309	2004	981902491.978	20.907	2.091	2.091		-15.803	-0.069	-0.426	-0.090	384.450	0.003	25.289	1008.236	100	0
12	22:58:15	309	2004	981902488.930	18.815	1.882	1.882		-3.878	0.082	-0.486	-0.090	384.450	0.003	25.327	1008.036	100	0
13	23:58:15	309	2004	981902488.020	22.987	2.299	2.299		7.671	0.236	-0.525	-0.090	384.450	0.003	25.315	1007.906	100	0
14	00:58:15	310	2004	981902486.995	18.819	1.882	1.882		17.797	0.353	-0.684	-0.090	384.450	0.003	25.290	1007.375	100	0
15	01:58:15	310	2004	981902494.173	19.500	1.950	1.950		25.269	0.399	-0.843	-0.090	384.450	0.003	25.277	1006.846	100	0
16	02:58:15	310	2004	981902492.540	16.864	1.686	1.686		28.891	0.357	-0.923	-0.090	384.450	0.003	25.263	1006.577	100	0
17	03:58:14	310	2004	981902490.245	16.949	1.703	1.703		27.757	0.233	-0.993	-0.090	384.450	0.003	25.284	1006.343	99	1
18	04:58:15	310	2004	981902491.780	16.332	1.633	1.633		21.494	0.050	-1.051	-0.090	384.450	0.003	25.270	1006.151	100	0
19	05:58:15	310	2004	981902495.386	24.221	2.422	2.422		10.424	-0.153	-1.115	-0.090	384.450	0.003	25.169	1005.937	100	0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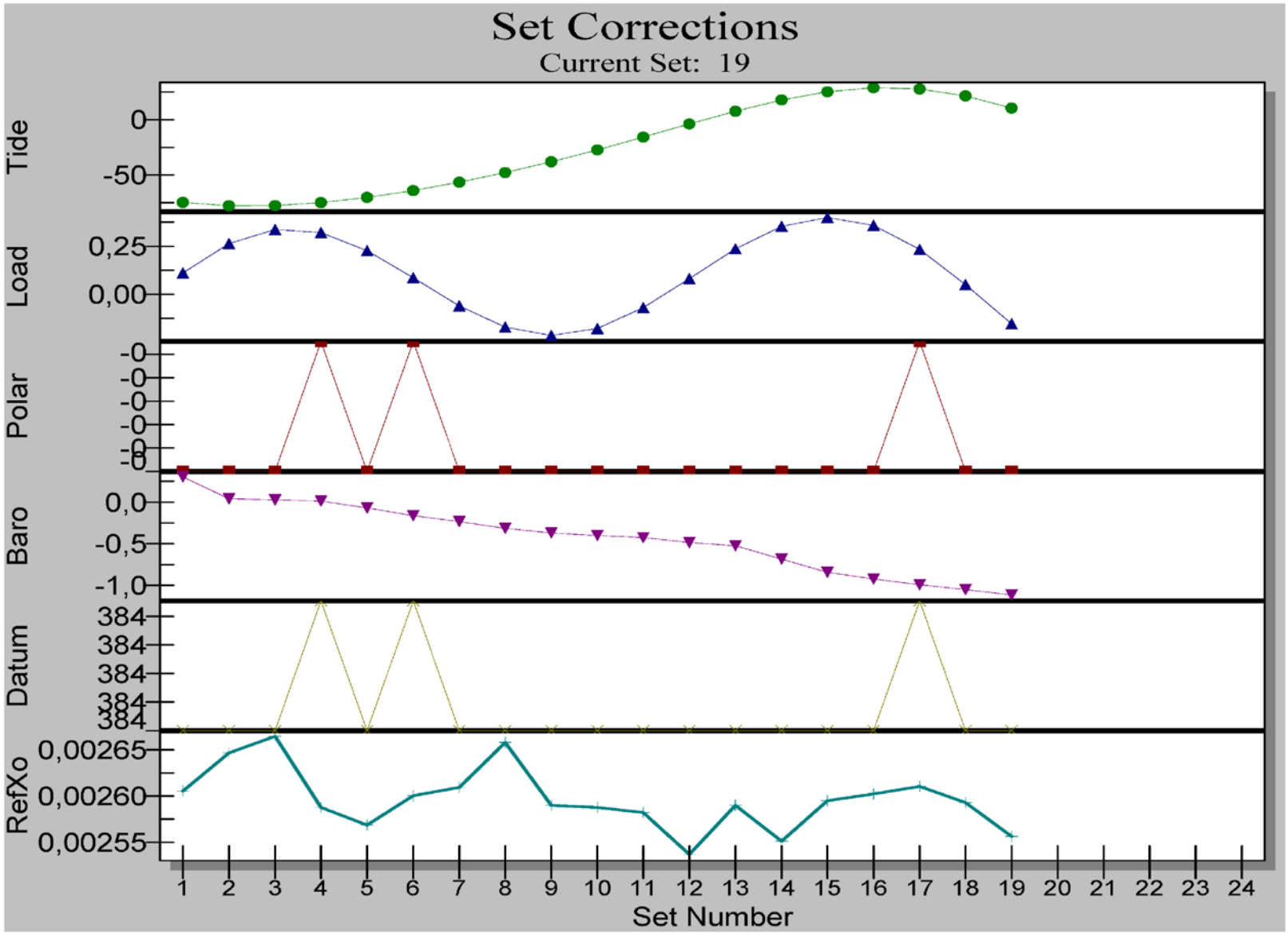
5,0
2,5
0,0
-2,5
-5,0
-7,5
uGal
15:00
18:00
21:00
Fri 5
3:00
6:00
Thu 4 Nov 2004
time


Set Corrections
Current Set: 19
Tide
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Load
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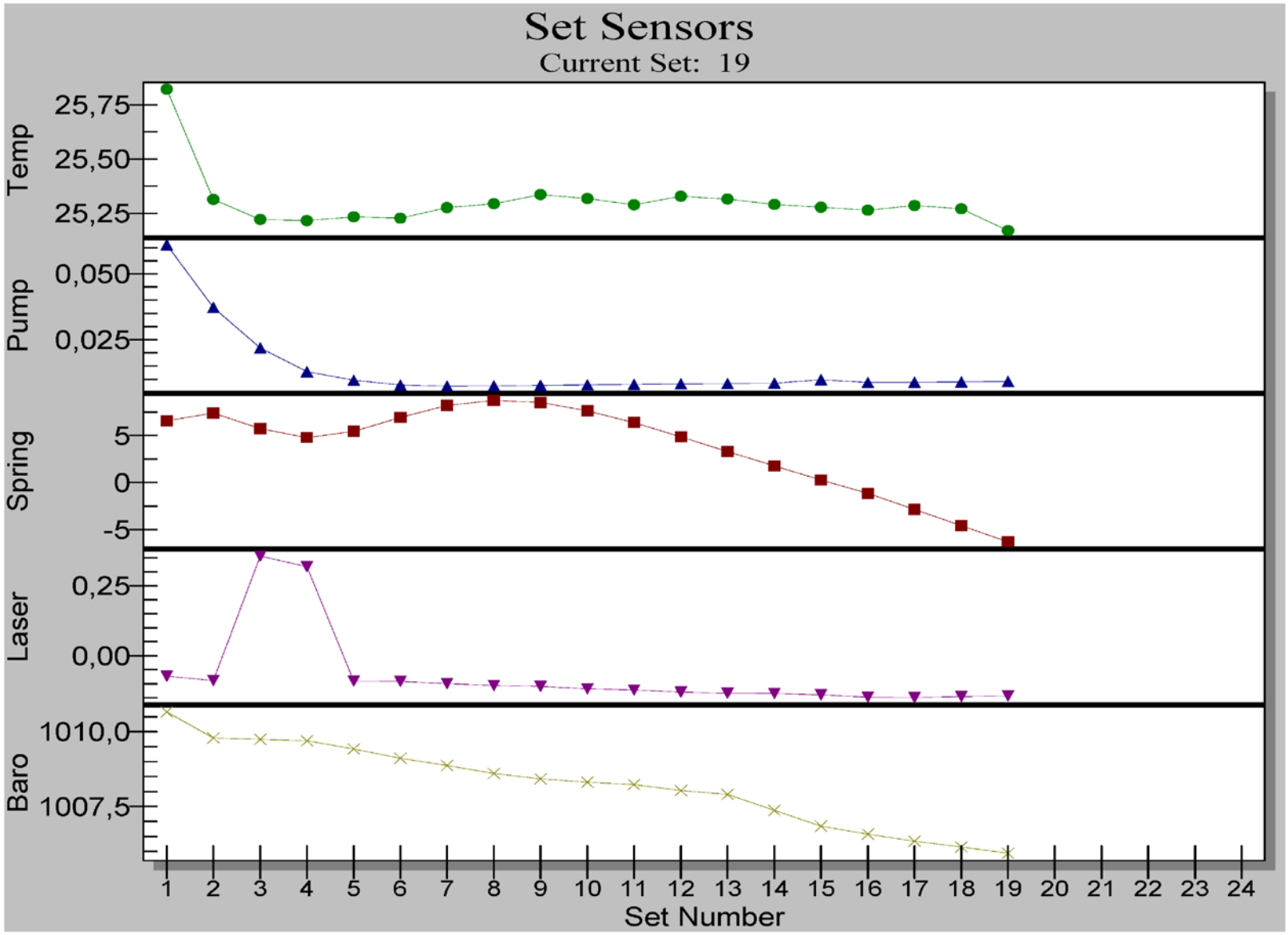
0,00
Polar
Baro
0,0
-0,5
-1,0
Datum
384
RefXo
0,00265
0,00260
0,00255
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Set Number


Set Sensors
Current Set: 19
Temp
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25,25
Pump
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0,025
Spring
5
0
-5
Laser
0,25
0,00
Baro
1010,0
1007,5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Set Number

5-6 Nov. 2004

STATION: SAINT-PETERSBURG

City:	Lomonosov	Country:	Russia
Location:	VNIIM	Particularity:	
Situation:	Gravity site	Remarks:	
Date:	5/6 November 2004		

Code number:	
Latitude:	59.8908 degrees
Longitude:	29.7862 degrees
Elevation:	29.97 m
Gradient:	-3.000 μgal/cm
Reference height:	11.75 mm
Meter:	FG5
S/N:	216

Ocean loading correction (μgal, -Greenwich degree)

Wave	M_2	S_2	K_1	O_1	N_2	P_1	K_2	Q_1	M_f	M_m	S_{sa}
Ampl.	0.510	0.155	0.041	0.143	0.091	0.010	0.040	0.042	0.0	0.0	0.0
Phase:	16.4	-12.0	-18.2	129.3	36.9	31.0	-30.4	-190.0	0.0	0.0	0.0

Polar motion correction			**Air pressure correction**	
X-coordinate:	0.2078	arc seconds	Nominal air pressure:	109.65 mbar
Y-coordinate:	0.3521	arc seconds	Barometric admittance factor:	0.3 μgal/mbar

Gravity

Set gravity mean:	**9 81 902 491.45**	microgal
Set std. dev.:	0.94	microgal
Mean std. dev.:	21.64	microgal
Number of sets:	29	
Number of drops per set:	200	
Drop interval:	5 seconds	
Set interval:	60 minutes	
Nominal/datum height:	0.0 cm	

Author: O. Francis
European Center for Geodynamics and Seismology
Date: January 9, 2005

Project file

Micro-g Solutions g Processing Report
File Created: 01/03/05, 16:31:03

Project Name: SP20041105
g Acquisition Version: 1.0823
g Processing Version: 4.0405

Company/Institution: ECGS
Operator: Olivier Francis

Station Data
Name: Saint-Petersbourg
Site Code: Gravity point VNIIM
Lat: 59.89079 Long: 29.78620 Elev: 29.97 m
Reference Height: 11.75 cm
Datum Height: 0.00 cm
Gradient: -3.000 uGal/cm
Nominal Air Pressure: 1009.65 mBar
Barometric Admittance Factor: 0.30
Polar Motion Coord: 0.2080 " 0.3493 "
Earth Tide (ETGTAB) Selected
Potential Filename: C:\Program Files\Micro-g Solutions Inc\gWavefiles\Etcpot.dat
Delta Factor Filename: F:\absolu\DATA\2004\FG5-216\StPetersbourg\OceanLoad.dff
Delta Factors

Start	Stop	Amplitude	Phase	Term
0.000000	0.002427	1.000000	0.0000	DC
0.002428	0.249951	1.160000	0.0000	Long
0.721500	0.906315	1.154250	0.0000	Q1
0.921941	0.974188	1.154240	0.0000	O1
0.989049	0.998028	1.149150	0.0000	P1
0.999853	1.216397	1.134890	0.0000	K1
1.719381	1.906462	1.161720	0.0000	N2
1.923766	1.976926	1.161720	0.0000	M2
1.991787	2.002885	1.161720	0.0000	S2
2.003032	2.182843	1.161720	0.0000	K2
2.753244	3.081254	1.07338	0.0000	M3
3.791964	3.937897	1.03900	0.0000	M4

Ocean Load ON, Filename: F:\absolu\DATA\2004\FG5-216\StPetersbourg\OceanLoad.olf

Waves:	M2	S2	K1	O1	N2	P1	K2	Q1	Mf	Mm	Ssa
Amplitude (uGal):	0.510	0.155	0.041	0.143	0.091	0.010	0.040	0.042	0.000	0.000	0.000
Phase (deg):	-16.4	12.0	18.2	-129.3	-36.9	-31.0	30.4	190.0	0.0	0.0	0.0

Instrument Data
Meter Type: FG5
Meter S/N: 216
Factory Height: 116.40 cm
Rubidium Frequency: 10000000.01020 Hz
Laser: WEO (187)
ID: 632.99117754 nm (0.41 V)
IE: 632.99119473 nm (-0.05 V)
IF: 632.99121259 nm (-0.43 V)
IG: 632.99123023 nm (-0.80 V)
IH: 632.99136890 nm (-1.60 V)

II: 632.99139822 nm (-1.49 V)
IJ: 632.99142704 nm (-1.40 V)
Modulation Frequency: 8333.420 Hz

Processing Results
Date: 11/05/04
Time: 21:48:17
DOY: 310
Year: 2004
Gravity: 981902491.45 uGal
Set Scatter: 0.94 uGal
Measurement Precision: 0.17 uGal
Total Uncertainty: 0.17 uGal
Number of Sets Collected: 29
Number of Sets Processed: 29
Set #s Processed: 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29
Number of Sets NOT Processed: 0
Set #s NOT Processed:
Number of Drops/Set: 200
Total Drops Accepted: 5786
Total Drops Rejected: 14
Total Fringes Acquired: 700
Fringe Start: 20
Processed Fringes: 600
GuideCard Multiplex: 4
GuideCard Scale Factor: 250

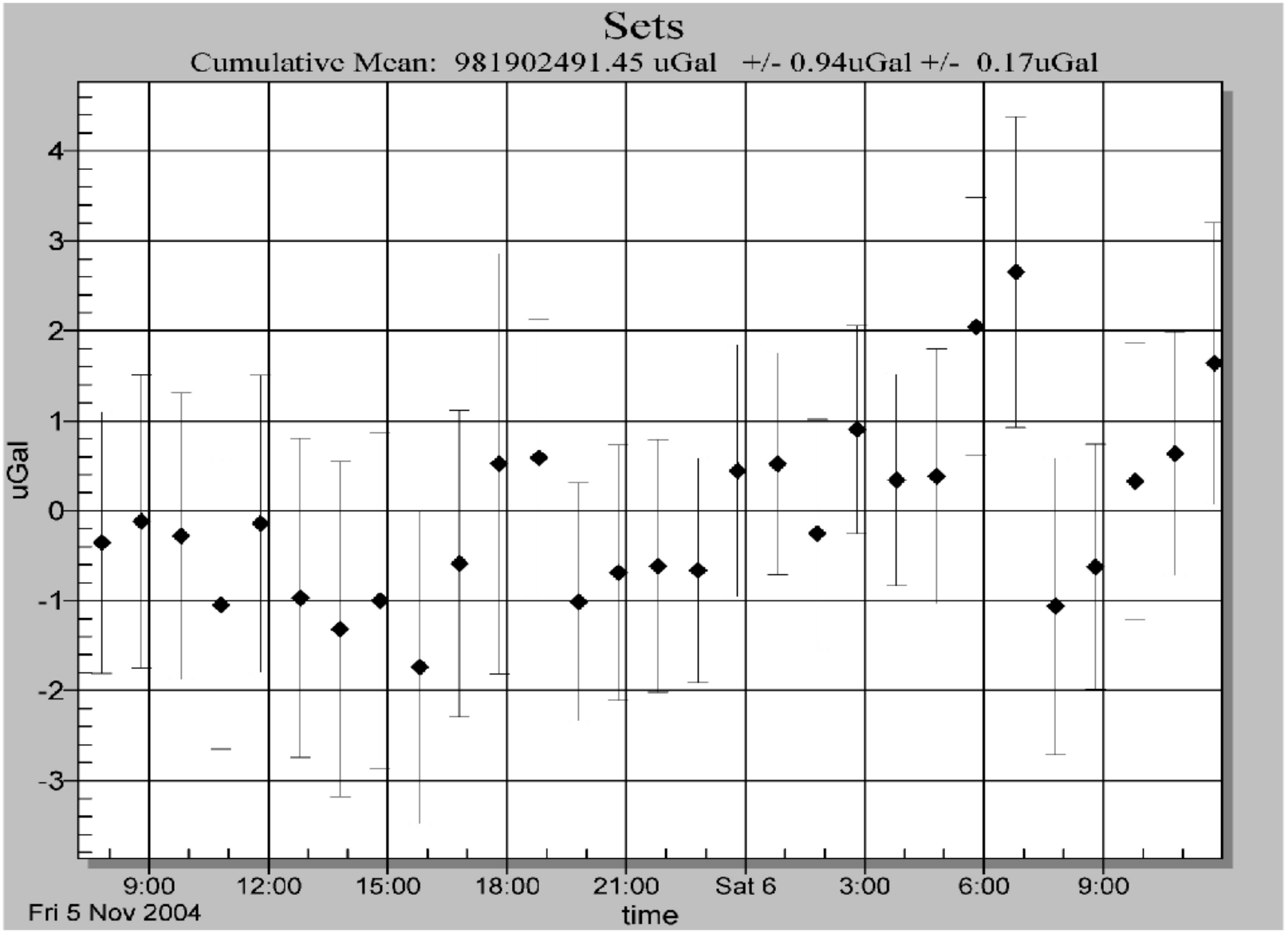
Gravity Corrections
Earth Tide (ETGTAB): -36.70 uGal
Ocean Load: -0.05 uGal
Polar Motion: -0.12 uGal
Barometric Pressure: -3.19 uGal
Datum Height: 384.45 uGal
Reference Xo: 0.00 uGal

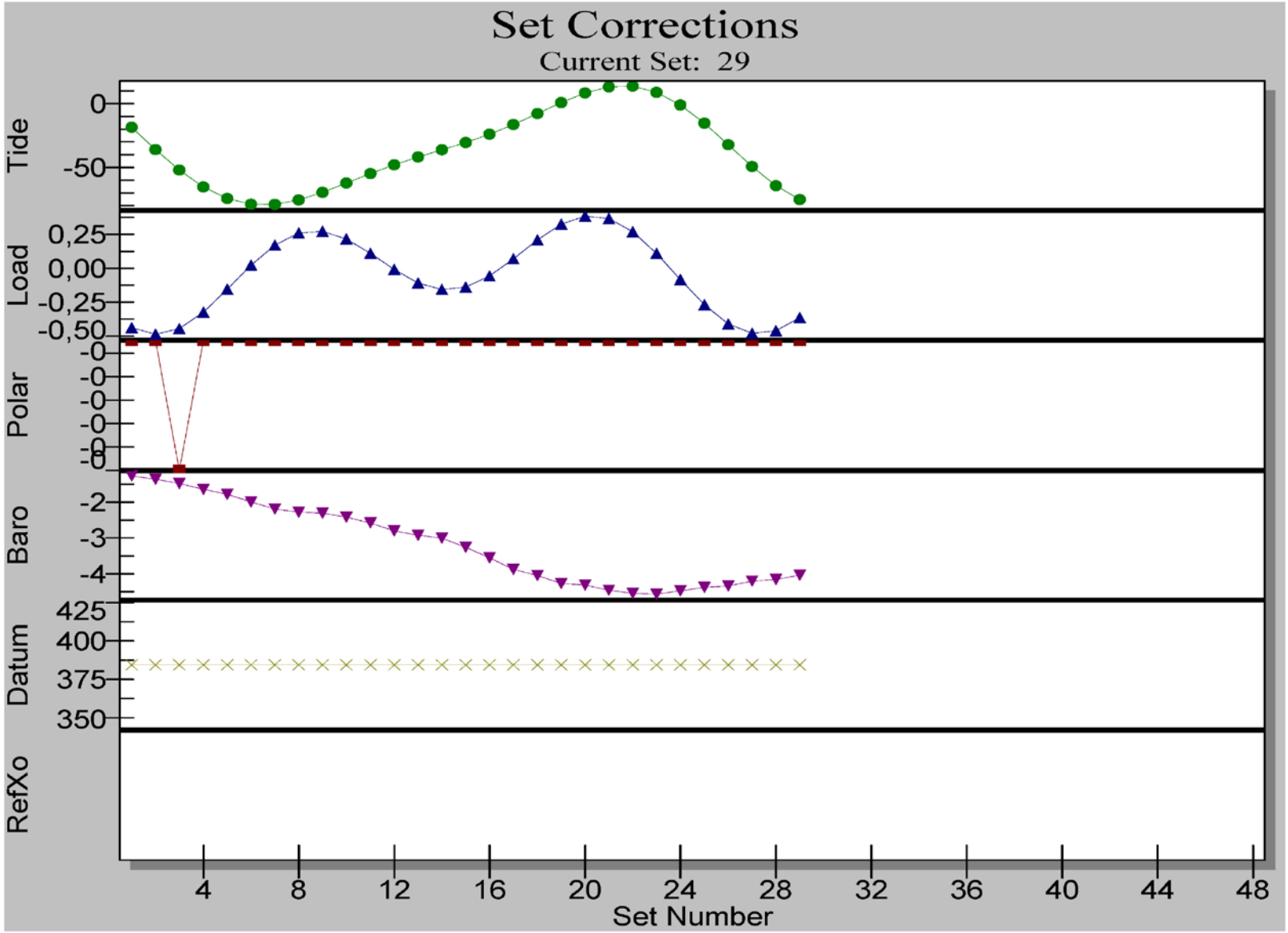
Uncertainties
Earth Tide Factor: 0.000
Average Earth Tide Uncertainty: 0.00 uGal
Ocean Load Factor: 0.00
Average Ocean Load Uncertainty: 0.00 uGal
Barometric: 0.00 uGal
Polar Motion: 0.00 uGal
Laser: 0.00 uGal
Clock: 0.00 uGal
System Type: 0.00 uGal
Tidal Swell: 0.00 uGal
Water Table: 0.00 uGal
Unmodeled: 0.00 uGal
System Setup: 0.00 uGal
Gradient: 0.00 uGal (0.00 uGal/cm)

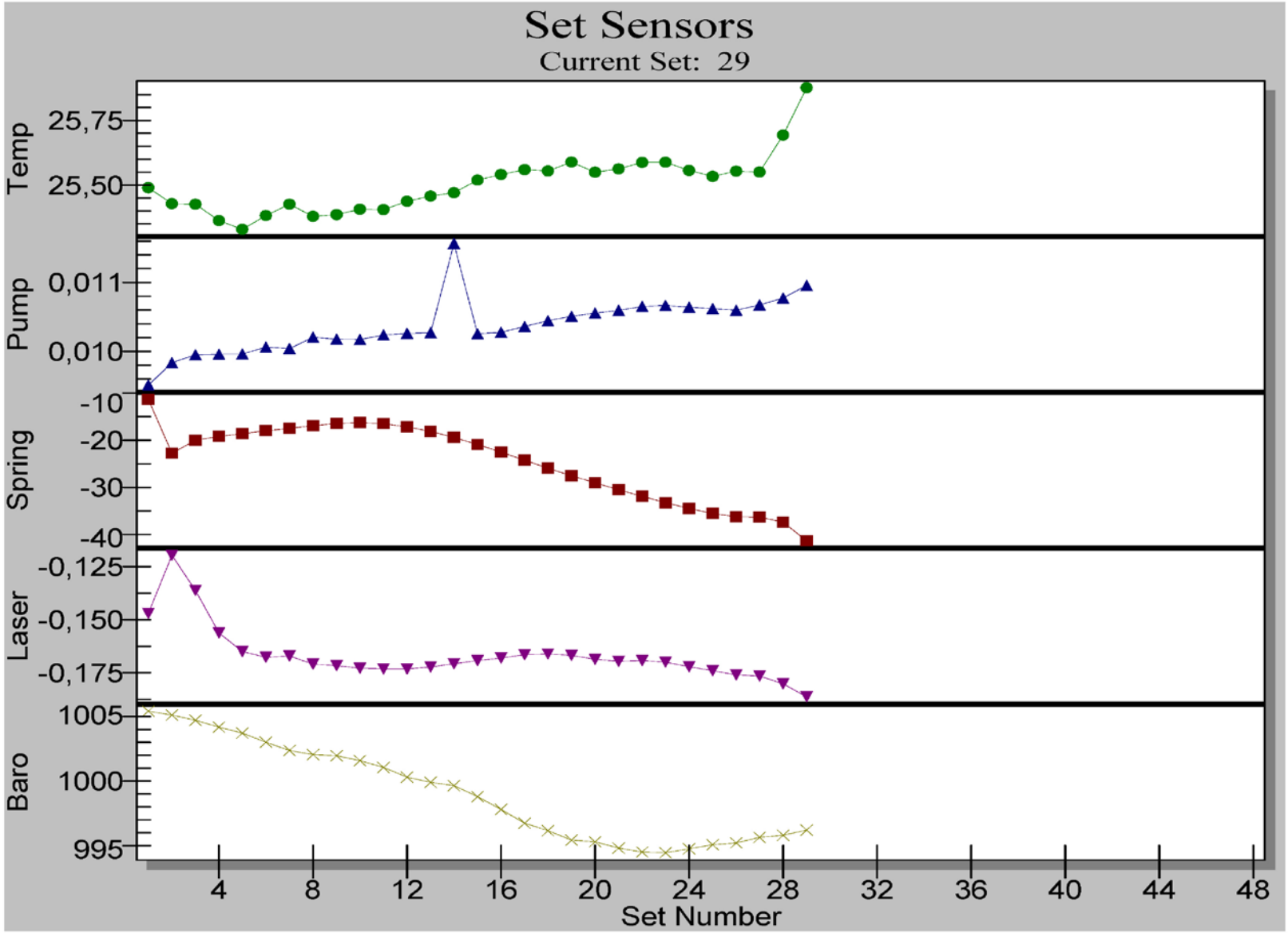
Set File

Source Data Filename: SP20041105
g Acquisition Version: 1.0823
g Processing Version: 4.0405

Set	Time	DOY	Year	Gravity	Sigma	Error	Uncert	Tide	Load	Baro	Polar	Datum	Refxo	Temp	Pres	Accept	Reject
1	07:48:17	310	2004	981902491.098	20.575	1.455	1.455	-18.584	-0.438	-1.269	-0.116	384.450	0.003	25.489	1005.426	200	0
2	08:48:17	310	2004	981902491.334	23.026	1.628	1.628	-36.023	-0.487	-1.362	-0.116	384.450	0.003	25.428	1005.114	200	0
3	09:48:11	310	2004	981902491.172	22.332	1.595	1.595	-52.135	-0.445	-1.481	-0.116	384.450	0.003	25.426	1004.720	196	4
4	10:48:17	310	2004	981902490.405	22.679	1.604	1.604	-65.343	-0.324	-1.641	-0.116	384.450	0.003	25.362	1004.186	200	0
5	11:48:17	310	2004	981902491.309	23.345	1.651	1.651	-74.426	-0.155	-1.778	-0.116	384.450	0.003	25.328	1003.727	200	0
6	12:48:17	310	2004	981902490.482	25.094	1.774	1.774	-78.928	0.023	-1.993	-0.116	384.450	0.003	25.382	1003.013	200	0
7	13:48:17	310	2004	981902490.135	26.342	1.863	1.863	-79.045	0.172	-2.188	-0.116	384.450	0.003	25.426	1002.361	200	0
8	14:48:17	310	2004	981902490.453	26.463	1.871	1.871	-75.542	0.260	-2.281	-0.116	384.450	0.003	25.379	1002.052	200	0
9	15:48:20	310	2004	981902489.714	24.526	1.739	1.739	-69.549	0.273	-2.306	-0.116	384.450	0.003	25.386	1001.969	199	1
10	16:48:17	310	2004	981902490.865	23.928	1.700	1.700	-62.319	0.216	-2.418	-0.116	384.450	0.003	25.406	1001.596	198	2
11	17:48:17	310	2004	981902491.974	33.027	2.335	2.335	-54.915	0.111	-2.580	-0.116	384.450	0.003	25.405	1001.056	200	0
12	18:48:17	310	2004	981902492.042	21.831	1.544	1.544	-48.042	-0.009	-2.802	-0.116	384.450	0.003	25.437	1000.314	200	0
13	19:48:17	310	2004	981902490.439	18.747	1.326	1.326	-41.906	-0.108	-2.924	-0.116	384.450	0.003	25.458	999.908	200	0
14	20:48:17	310	2004	981902490.764	20.103	1.422	1.422	-36.239	-0.156	-3.005	-0.116	384.450	0.003	25.470	999.639	200	0
15	21:48:17	310	2004	981902490.836	19.858	1.404	1.404	-30.461	-0.139	-3.256	-0.116	384.450	0.003	25.519	998.801	200	0
16	22:48:17	310	2004	981902490.790	17.548	1.247	1.247	-23.953	-0.057	-3.554	-0.116	384.450	0.003	25.540	997.808	198	2
17	23:48:17	310	2004	981902491.896	19.804	1.400	1.400	-16.350	0.070	-3.876	-0.116	384.450	0.003	25.560	996.734	200	0
18	00:48:17	311	2004	981902491.974	17.430	1.232	1.232	-7.813	0.210	-4.048	-0.116	384.450	0.003	25.554	996.160	200	0
19	01:48:19	311	2004	981902491.200	17.892	1.268	1.268	0.883	0.326	-4.268	-0.116	384.450	0.003	25.589	995.429	199	1
20	02:48:17	311	2004	981902492.356	16.373	1.158	1.158	8.395	0.385	-4.310	-0.116	384.450	0.003	25.549	995.289	200	0
21	03:48:17	311	2004	981902491.794	16.609	1.174	1.174	13.135	0.367	-4.457	-0.116	384.450	0.003	25.562	994.799	200	0
22	04:48:16	311	2004	981902491.835	19.933	1.413	1.413	13.622	0.270	-4.545	-0.116	384.450	0.003	25.587	994.504	199	1
23	05:48:17	311	2004	981902493.497	20.261	1.433	1.433	8.920	0.110	-4.564	-0.116	384.450	0.003	25.588	994.441	200	0
24	06:48:16	311	2004	981902494.105	24.311	1.728	1.728	-1.035	-0.083	-4.471	-0.116	384.450	0.003	25.557	994.753	198	2
25	07:48:17	311	2004	981902490.390	23.255	1.644	1.644	-15.354	-0.269	-4.377	-0.116	384.450	0.003	25.533	995.065	200	0
26	08:48:17	311	2004	981902490.828	19.288	1.364	1.364	-32.246	-0.411	-4.335	-0.116	384.450	0.003	25.554	995.204	200	0
27	09:48:17	311	2004	981902491.779	21.763	1.539	1.539	-49.401	-0.478	-4.205	-0.116	384.450	0.003	25.550	995.640	200	0
28	10:48:19	311	2004	981902492.085	19.044	1.350	1.350	-64.424	-0.461	-4.156	-0.116	384.450	0.003	25.693	995.803	199	1
29	11:48:17	311	2004	981902493.092	22.150	1.566	1.566	-75.282	-0.364	-4.035	-0.116	384.450	0.003	25.877	996.206	200	0


Sets
Cumulative Mean: 981902491.45 uGal +/- 0.94uGal +/- 0.17uGal
uGal
4
3
2
1
0
-1
-2
-3
9:00
12:00
15:00
18:00
21:00
Sat 6
3:00
6:00
9:00
Fri 5 Nov 2004
time


Set Corrections
Current Set: 29
Tide
0
-50
Load
0,25
0,00
-0,25
-0,50
Polar
Baro
-2
-3
-4
Datum
425
400
375
350
RefXo
4
8
12
16
20
24
28
32
36
40
44
48
Set Number


Set Sensors
Current Set: 29
Temp
25,75
25,50
Pump
0,011
0,010
Spring
-10
-20
-30
-40
Laser
-0,125
-0,150
-0,175
Baro
1005
1000
995
4
8
12
16
20
24
28
32
36
40
44
48
Set Number

4-6 Nov. 2004

STATION: SAINT-PETERSBURG

City:	Lomonosov	Country:	Russia
Location:	VNIIM	Particularity:	
Situation:	Gravity site	Remarks:	
Date:	4/6 November 2004		

Code number:	
Latitude:	59.8908 degrees
Longitude:	29.7862 degrees
Elevation:	29.97 m
Gradient:	-3.000 μgal/cm
Reference height:	11.75 mm
Meter:	FG5
S/N:	216

Ocean loading correction (μgal, -Greenwich degree)

Wave	M_2	S_2	K_1	O_1	N_2	P_1	K_2	Q_1	M_f	M_m	S_{sa}
Ampl.	0.510	0.155	0.041	0.143	0.091	0.010	0.040	0.042	0.0	0.0	0.0
Phase:	16.4	-12.0	-18.2	129.3	36.9	31.0	-30.4	-190.0	0.0	0.0	0.0

Polar motion correction			**Air pressure correction**	
X-coordinate:	0.2078	arc seconds	Nominal air pressure:	109.65 mbar
Y-coordinate:	0.3521	arc seconds	Barometric admittance factor:	0.3 μgal/mbar

Gravity

Set gravity mean:	**9 81 902 491.45**	microgal
Set std. dev.:	1.91	microgal
Mean std. dev.:	21.40	microgal
Number of sets:	48	
Number of drops per set:	100/200	
Drop interval:	10/5 seconds	
Set interval:	60 minutes	
Nominal/datum height:	0.0 cm	

Author: O. Francis
European Center for Geodynamics and Seismology
Date: January 9, 2005

Project file

Micro-g Solutions g Processing Report
File Created: 01/03/05, 16:38:06

Project Name: sp2004110405
g Acquisition Version: 1.0823
g Processing Version: 4.0405

Company/Institution: ECGS
Operator: Olivier

Station Data
Name: Saint-Petersbourg
Site Code: Gravity point VNIIM
Lat: 59.89079 Long: 29.78620 Elev: 29.97 m
Reference Height: 11.75 cm
Datum Height: 0.00 cm
Gradient: -3.000 uGal/cm
Nominal Air Pressure: 1009.65 mBar
Barometric Admittance Factor: 0.30
Polar Motion Coord: 0.2080 " 0.3493 "
Earth Tide (ETGTAB) Selected
Potential Filename: C:\Program Files\Micro-g Solutions Inc\gWavefiles\Etcpot.dat
Delta Factor Filename: F:\absolu\DATA\2004\FG5-216\StPetersbourg\OceanLoad.dff
Delta Factors

Start	Stop	Amplitude	Phase	Term
0.000000	0.002427	1.000000	0.0000	DC
0.002428	0.249951	1.160000	0.0000	Long
0.721500	0.906315	1.154250	0.0000	Q1
0.921941	0.974188	1.154240	0.0000	O1
0.989049	0.998028	1.149150	0.0000	P1
0.999853	1.216397	1.134890	0.0000	K1
1.719381	1.906462	1.161720	0.0000	N2
1.923766	1.976926	1.161720	0.0000	M2
1.991787	2.002885	1.161720	0.0000	S2
2.003032	2.182843	1.161720	0.0000	K2
2.753244	3.081254	1.07338	0.0000	M3
3.791964	3.937897	1.03900	0.0000	M4

Ocean Load ON, Filename: F:\absolu\DATA\2004\FG5-216\StPetersbourg\OceanLoad.olf

Waves:	M2	S2	K1	O1	N2	P1	K2	Q1	Mf	Mm	Ssa
Amplitude (uGal):	0.510	0.155	0.041	0.143	0.091	0.010	0.040	0.042	0.000	0.000	0.000
Phase (deg):	-16.4	12.0	18.2	-129.3	-36.9	-31.0	30.4	190.0	0.0	0.0	0.0

Instrument Data
Meter Type: FG5
Meter S/N: 216
Factory Height: 116.40 cm
Rubidium Frequency: 10000000.01020 Hz
Laser: WEO (187)
ID: 632.99117754 nm (0.41 V)
IE: 632.99119473 nm (-0.05 V)
IF: 632.99121259 nm (-0.43 V)
IG: 632.99123023 nm (-0.80 V)
IH: 632.99136890 nm (-1.60 V)

II: 632.99139822 nm (-1.49 V)
IJ: 632.99142704 nm (-1.40 V)
Modulation Frequency: 8333.420 Hz

Processing Results
Date: 11/05/04
Time: 11:55:58
DOY: 310
Year: 2004
Gravity: 981902491.45 uGal
Set Scatter: 1.91 uGal
Measurement Precision: 0.28 uGal
Total Uncertainty: 0.28 uGal
Number of Sets Collected: 48
Number of Sets Processed: 48
Set #s Processed:
1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48
Number of Sets NOT Processed: 0
Set #s NOT Processed:
Number of Drops/Set: 100
Total Drops Accepted: 4793
Total Drops Rejected: 7
Total Fringes Acquired: 700
Fringe Start: 20
Processed Fringes: 600
GuideCard Multiplex: 4
GuideCard Scale Factor: 250

Gravity Corrections
Earth Tide (ETGTAB): -32.29 uGal
Ocean Load: 0.01 uGal
Polar Motion: -0.12 uGal
Barometric Pressure: -2.09 uGal
Datum Height: 384.45 uGal
Reference Xo: 0.00 uGal

Uncertainties
Earth Tide Factor: 0.000
Average Earth Tide Uncertainty: 0.00 uGal
Ocean Load Factor: 0.00
Average Ocean Load Uncertainty: 0.00 uGal
Barometric: 0.00 uGal
Polar Motion: 0.00 uGal
Laser: 0.00 uGal
Clock: 0.00 uGal
System Type: 0.00 uGal
Tidal Swell: 0.00 uGal
Water Table: 0.00 uGal
Unmodeled: 0.00 uGal
System Setup: 0.00 uGal
Gradient: 0.00 uGal (0.00 uGal/cm)

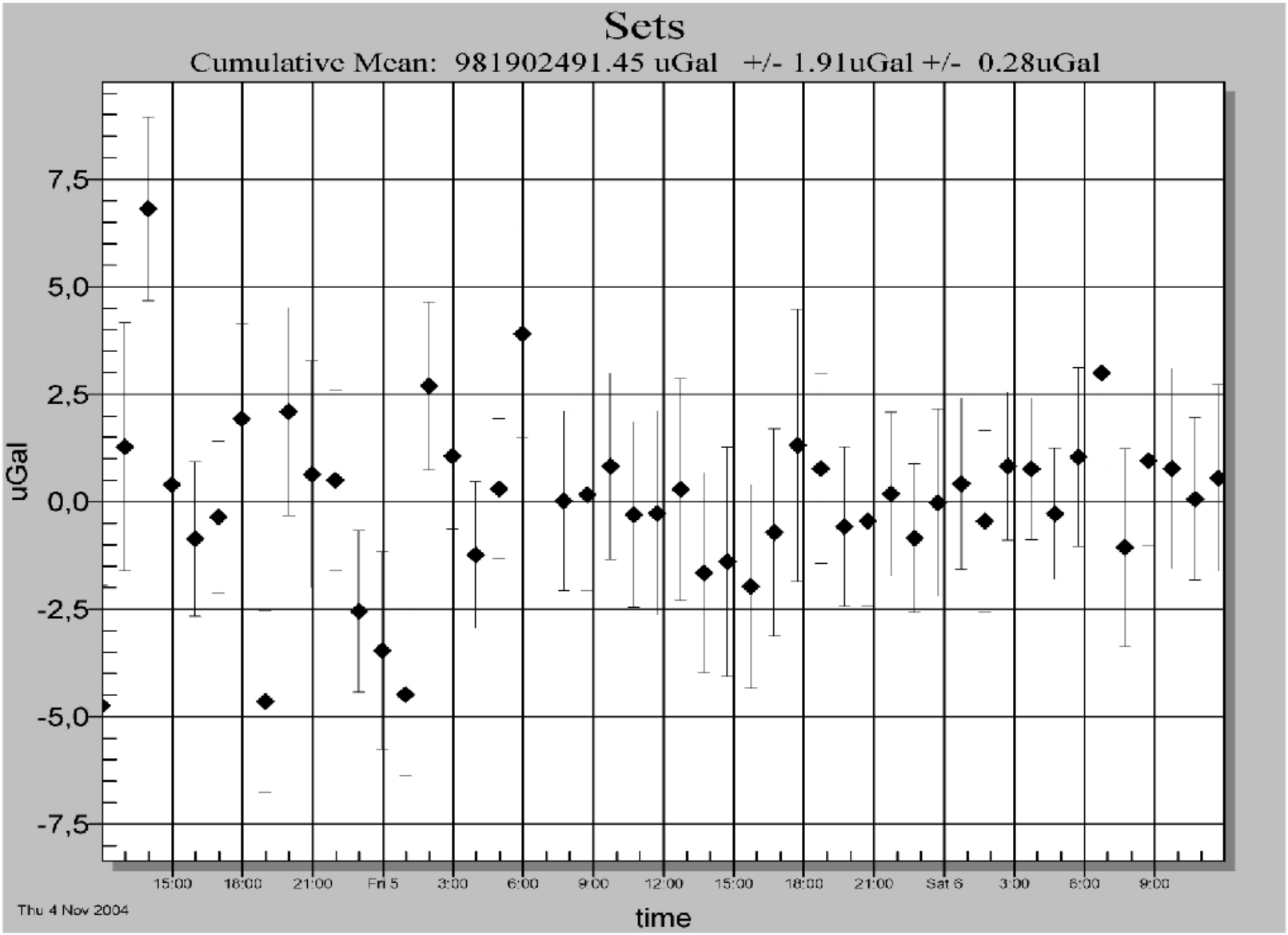
Files Merged: SP20041104.fg5 and SP20041105.FG5

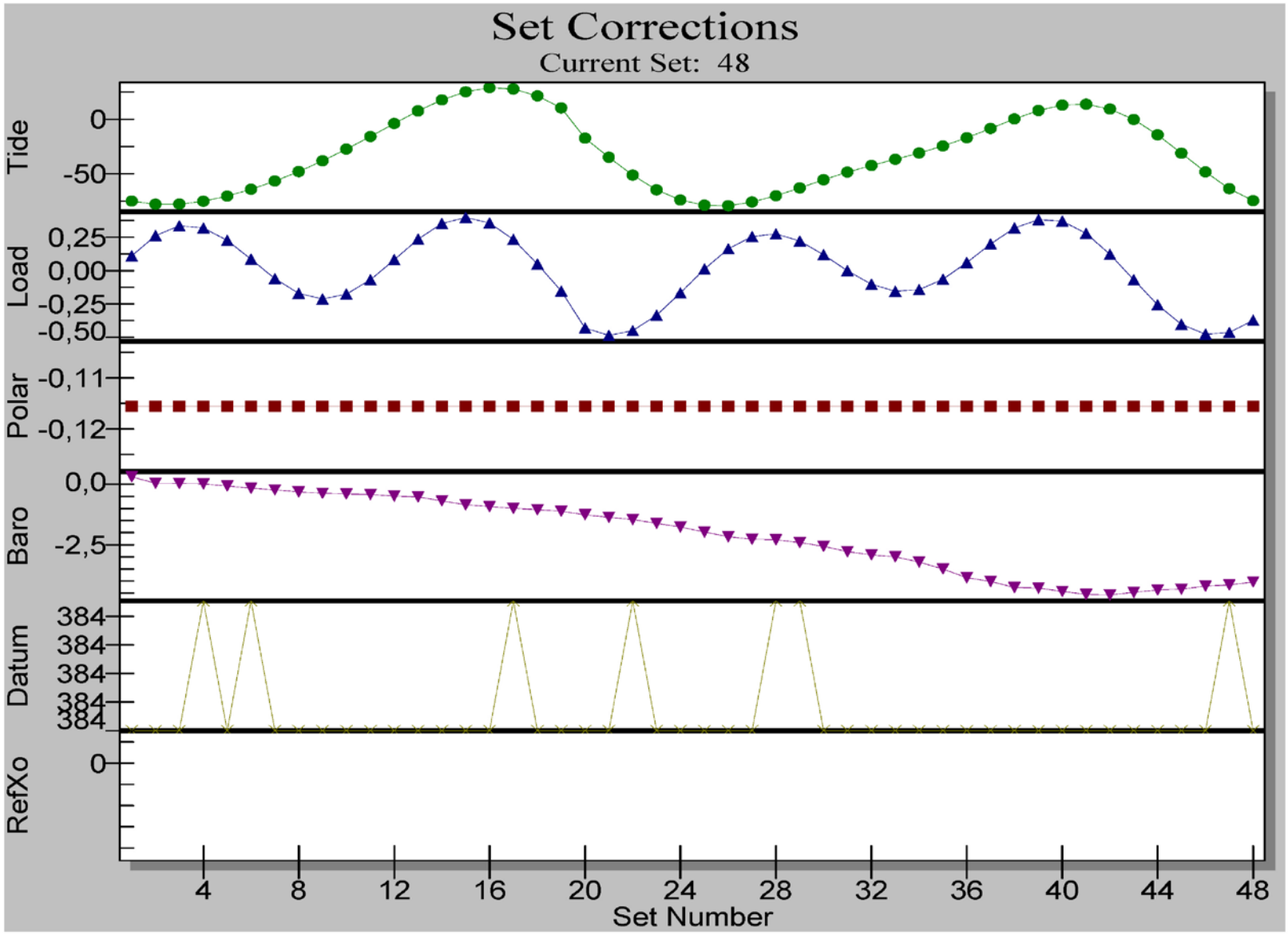
Set File

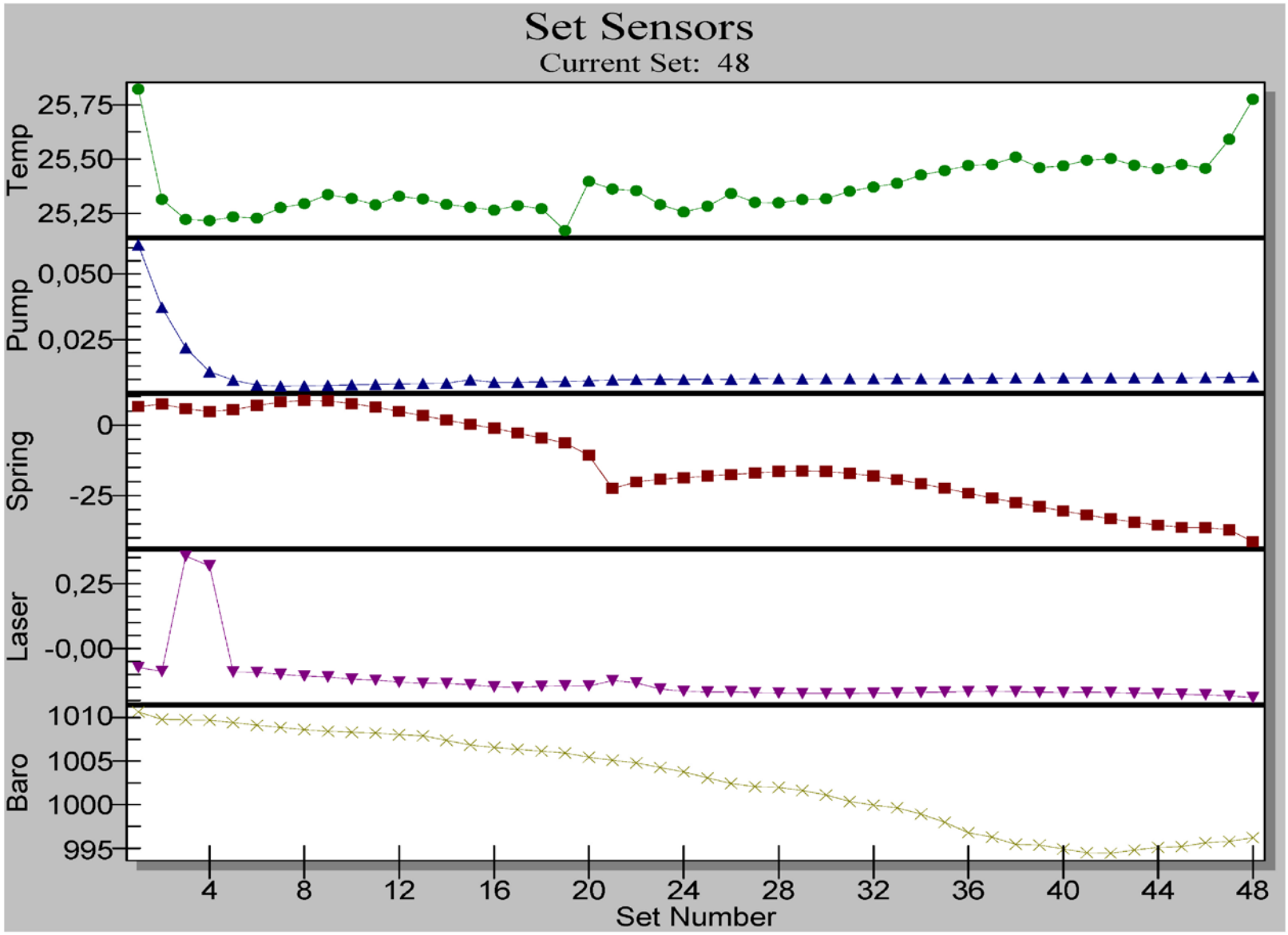
Source Data Filename: sp2004110405
g Acquisition Version: 1.0823
g Processing Version: 4.0405

Set	Time	DOY	Year	Gravity	Sigma	Error	Uncert	Tide	Load	Baro	Polar	Datum	Refxo	Temp	Pres	Accept	Reject	
1	11:58:15	309	2004	981902486.714	28.013	2.801	2.801		-74.922	0.111	0.304	-0.116	384.450	0.003	25.822	1010.668	100	0
2	12:58:15	309	2004	981902492.730	28.842	2.884	2.884		-77.871	0.263	0.042	-0.116	384.450	0.003	25.313	1009.794	100	0
3	13:58:15	309	2004	981902498.268	21.351	2.135	2.135		-77.744	0.336	0.028	-0.116	384.450	0.003	25.221	1009.750	100	0
4	14:58:15	309	2004	981902491.847	21.012	2.112	2.112		-75.068	0.320	0.013	-0.116	384.450	0.003	25.215	1009.699	99	1
5	15:58:15	309	2004	981902490.591	18.033	1.803	1.803		-70.373	0.227	-0.069	-0.116	384.450	0.003	25.233	1009.425	100	0
6	16:58:16	309	2004	981902491.096	17.552	1.764	1.764		-64.095	0.086	-0.162	-0.116	384.450	0.003	25.226	1009.116	99	1
7	17:58:15	309	2004	981902493.380	22.206	2.221	2.221		-56.539	-0.060	-0.235	-0.116	384.450	0.003	25.276	1008.873	100	0
8	18:58:15	309	2004	981902486.809	21.025	2.103	2.103		-47.853	-0.170	-0.314	-0.116	384.450	0.003	25.294	1008.608	100	0
9	19:58:15	309	2004	981902493.552	24.219	2.422	2.422		-38.104	-0.213	-0.369	-0.116	384.450	0.003	25.336	1008.424	100	0
10	20:58:15	309	2004	981902492.092	26.367	2.637	2.637		-27.357	-0.177	-0.402	-0.116	384.450	0.003	25.318	1008.315	100	0
11	21:58:15	309	2004	981902491.953	20.907	2.091	2.091		-15.803	-0.069	-0.426	-0.116	384.450	0.003	25.289	1008.236	100	0
12	22:58:15	309	2004	981902488.905	18.815	1.882	1.882		-3.878	0.082	-0.486	-0.116	384.450	0.003	25.327	1008.036	100	0
13	23:58:15	309	2004	981902487.995	22.987	2.299	2.299		7.671	0.236	-0.525	-0.116	384.450	0.003	25.315	1007.906	100	0
14	00:58:15	310	2004	981902486.970	18.819	1.882	1.882		17.797	0.353	-0.684	-0.116	384.450	0.003	25.290	1007.375	100	0
15	01:58:15	310	2004	981902494.147	19.500	1.950	1.950		25.269	0.399	-0.843	-0.116	384.450	0.003	25.277	1006.846	100	0
16	02:58:15	310	2004	981902492.514	16.864	1.686	1.686		28.891	0.357	-0.923	-0.116	384.450	0.003	25.263	1006.577	100	0
17	03:58:14	310	2004	981902490.220	16.949	1.703	1.703		27.757	0.233	-0.993	-0.116	384.450	0.003	25.284	1006.343	99	1
18	04:58:15	310	2004	981902491.754	16.332	1.633	1.633		21.494	0.050	-1.051	-0.116	384.450	0.003	25.270	1006.151	100	0
19	05:58:15	310	2004	981902495.361	24.221	2.422	2.422		10.424	-0.153	-1.115	-0.116	384.450	0.003	25.169	1005.937	100	0
20	07:44:07	310	2004	981902491.473	20.930	2.093	2.093		-17.372	-0.432	-1.257	-0.116	384.450	0.003	25.396	1005.464	100	0
21	08:44:07	310	2004	981902491.621	22.362	2.236	2.236		-34.835	-0.486	-1.371	-0.116	384.450	0.003	25.361	1005.086	100	0
22	09:44:05	310	2004	981902492.278	21.571	2.168	2.168		-51.117	-0.450	-1.459	-0.116	384.450	0.003	25.353	1004.792	99	1
23	10:44:07	310	2004	981902491.155	21.632	2.163	2.163		-64.560	-0.335	-1.616	-0.116	384.450	0.003	25.289	1004.269	100	0
24	11:44:07	310	2004	981902491.185	23.753	2.375	2.375		-73.952	-0.168	-1.764	-0.116	384.450	0.003	25.255	1003.774	100	0
25	12:44:07	310	2004	981902491.741	25.761	2.576	2.576		-78.773	0.011	-1.975	-0.116	384.450	0.003	25.282	1003.073	100	0
26	13:44:07	310	2004	981902489.802	23.336	2.334	2.334		-79.174	0.163	-2.169	-0.116	384.450	0.003	25.341	1002.426	100	0
27	14:44:07	310	2004	981902490.058	26.589	2.659	2.659		-75.886	0.256	-2.275	-0.116	384.450	0.002	25.300	1002.073	100	0
28	15:44:09	310	2004	981902489.486	23.601	2.372	2.372		-70.024	0.275	-2.299	-0.116	384.450	0.003	25.298	1001.992	99	1
29	16:44:05	310	2004	981902490.741	23.977	2.410	2.410		-62.842	0.222	-2.411	-0.116	384.450	0.003	25.312	1001.618	99	1
30	17:44:07	310	2004	981902492.766	31.672	3.167	3.167		-55.416	0.119	-2.562	-0.116	384.450	0.003	25.317	1001.115	100	0

31	18:44:07	310	2004	981902492.225	22.090	2.209	2.209	-48.493	-0.001	-2.789	-0.116	384.450	0.003	25.351	1000.357	100	0
32	19:44:07	310	2004	981902490.875	18.515	1.852	1.852	-42.310	-0.102	-2.918	-0.116	384.450	0.003	25.371	999.929	100	0
33	20:44:07	310	2004	981902491.008	19.754	1.975	1.975	-36.628	-0.155	-3.003	-0.116	384.450	0.003	25.388	999.644	100	0
34	21:44:07	310	2004	981902491.636	19.056	1.906	1.906	-30.881	-0.142	-3.222	-0.116	384.450	0.003	25.426	998.916	100	0
35	22:44:07	310	2004	981902490.608	17.231	1.723	1.723	-24.440	-0.064	-3.502	-0.116	384.450	0.003	25.446	997.980	100	0
36	23:44:07	310	2004	981902491.428	21.745	2.174	2.174	-16.916	0.061	-3.864	-0.116	384.450	0.003	25.469	996.775	100	0
37	00:44:07	311	2004	981902491.869	19.967	1.997	1.997	-8.424	0.201	-4.018	-0.116	384.450	0.003	25.474	996.262	100	0
38	01:44:07	311	2004	981902491.003	21.054	2.105	2.105	0.298	0.319	-4.267	-0.116	384.450	0.003	25.508	995.431	100	0
39	02:44:07	311	2004	981902492.280	17.219	1.722	1.722	7.950	0.383	-4.292	-0.116	384.450	0.003	25.460	995.347	100	0
40	03:44:07	311	2004	981902492.218	16.546	1.655	1.655	12.938	0.371	-4.427	-0.116	384.450	0.003	25.468	994.898	100	0
41	04:44:07	311	2004	981902491.173	15.302	1.530	1.530	13.761	0.279	-4.554	-0.116	384.450	0.003	25.494	994.473	100	0
42	05:44:07	311	2004	981902492.493	20.778	2.078	2.078	9.434	0.122	-4.575	-0.116	384.450	0.003	25.501	994.406	100	0
43	06:44:07	311	2004	981902494.450	22.051	2.205	2.205	-0.182	-0.070	-4.466	-0.116	384.450	0.003	25.470	994.769	100	0
44	07:44:07	311	2004	981902490.391	23.060	2.306	2.306	-14.246	-0.258	-4.370	-0.116	384.450	0.003	25.454	995.087	100	0
45	08:44:07	311	2004	981902492.413	19.838	1.984	1.984	-31.035	-0.403	-4.342	-0.116	384.450	0.003	25.474	995.183	100	0
46	09:44:07	311	2004	981902492.226	23.276	2.328	2.328	-48.257	-0.477	-4.205	-0.116	384.450	0.003	25.456	995.640	100	0
47	10:44:09	311	2004	981902491.516	18.778	1.887	1.887	-63.503	-0.465	-4.166	-0.116	384.450	0.003	25.591	995.769	99	1
48	11:44:07	311	2004	981902492.007	21.725	2.173	2.173	-74.706	-0.373	-4.036	-0.116	384.450	0.003	25.776	996.203	100	0


Sets
Cumulative Mean: 981902491.45 uGal +/- 1.91uGal +/- 0.28uGal
7,5
5,0
2,5
0,0
-2,5
-5,0
-7,5
uGal
15:00
18:00
21:00
Fri 5
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Sat 6
3:00
6:00
9:00
Thu 4 Nov 2004
time


Set Corrections
Current Set: 48
Tide
0
-50
Load
0,25
0,00
-0,25
-0,50
Polar
-0,11
-0,12
Baro
0,0
-2,5
Datum
384
384
384
384
384
RefXo
0
4
8
12
16
20
24
28
32
36
40
44
48
Set Number


Set Sensors
Current Set: 48
Temp
25,75
25,50
25,25
Pump
0,050
0,025
Spring
0
-25
Laser
0,25
-0,00
Baro
1010
1005
1000
995
4
8
12
16
20
24
28
32
36
40
44
48
Set Number